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The usefulness of zirconium was limited until the metal could be separated from its twin, hafnium. Pure zirconium is important in the construction of nuclear reactors and has many other applications because of its properties. The possible uses of hafnium, however, are still largely unknown.

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Check and Double Check in Research

THE TREND IN PLANNING research towards highly specific economic goals—such as when industrial operations diagnosis is used—does not imply that any of the incidental values from less rigidly planned technical work will be lost. In fact, modern planning recognizes and embraces these values along with the need for clear definition of purpose.

As all research people know, many of the most important past discoveries in science have been accidental and could not have been predicted when the research was initiated. Industrial operations diagnosis leaves the way open for such incidental or accidental discoveries, but regards them as "bonus" values from the work.

Straight-line analytical planning also takes cognizance of the advantages that may come from following multiple approaches to the solution of a problem or from duplicating effort for the affirmative value of duplication. It is wholly consistent with modern research methods to initiate deliberately the same study in two laboratories. The results obtained by each group serve as a check on the results of the others, bring different slants, avoid bias in making conclusions, and lead to greater positiveness in the conclusions. This is not "duplication" in the sense of wasted effort, but is the same type of check and double check as used by, say, the analytical chemist when he runs his multiple determinations. It hastens applications of research results to industry by providing assurance of the soundness of the results.

Some highly progressive companies check and double check certain research studies by assigning the problem or parts of the problem to groups in different branches of their organization. Others engage outside laboratories, such as commercial laboratories, university foundations, or private research institutes to provide affirmative check on the work of their own research staff. If there is general agreement in the results, management can have more confidence in the investment of the capital required to put the results into use.

The practice of employing independent laboratories to check and double check upon research has highly desirable aspects. The outside viewpoint tends to be fresher. The personnel of outside laboratories do not know, or feel as keenly, the supposed limitations that may be accepted as gospel fact within the industry. As one company executive stated: "The laboratories we engage outside our plant don't know that a problem *can't* be solved!". A check on the validity of supposed limitations of science in solving an industrial problem is just as valuable as a check on the research data.

While the inadvertent duplication of research is a deplorable wastage of technical manpower and money, deliberate duplication is good scientific practice. It is intentional repetition for the sake of repetition, designed to help management decision. It usually means eventual savings of both manpower and money. Deliberate duplication of research for checking purposes is an important part of modern research planning.

Clyde Williams

President, Battelle Memorial Institute

Chemical Synthesis by Fermentation

by FREDERIC E. PORTER

Dr. Porter, an industrial and food microbiologist, has carried on investigations in X-ray sterilization, the production of bacterial cellulase, and methods of improving bacteriological techniques. His association with Battelle began in 1952. Before receiving his Ph.D. in bacteriology from The Ohio State University, Porter served as a laboratory instructor there. He is a member of the Society of American Bacteriologists and of Sigma Xi.

HISTORICALLY, FERMENTATION has been used for the preservation of food and the production of beverages. In recent years, however, the process has come to be employed in the production of materials important in industrial and medical fields. As a result of its origins, the term "fermentation" was restricted earlier to anaerobic processes, that is, processes where no free oxygen is present. Now, however, the definition has been relaxed to include aerobic processes involving free oxygen.

Chemical and fermentation processes are essentially the same. Nevertheless, for the purpose of this article, a distinction is made between the two in that biological synthesis refers to processes that are carried on through enzyme activity.

Generally speaking, it may be said that the production of materials by means of biological synthesis is likely to be somewhat limited because of production costs. Raw materials cost is one of the main factors. Carbohydrate such as molasses, cereal grains, and starchy tubers are some of the raw materials which are oxidized to produce energy in biological synthesis. The prices of these may fluctuate widely because of variations in consumption by the nation's livestock and the size of crops. Many of the chemical syntheses, on the other hand, use raw materials that are produced at a reasonably constant rate and cost, and this stabilizes prices.

The second factor contributing to the cost of biological syntheses is the necessity of carrying out fermentations by batch processes. It may be noted that all fermentations are carried out in batches, and that the fermentation times range from a minimum of 18 hours to a maximum of two weeks. Many of the fermentations are a combination of batch production and continuous separation processes. In order to keep stills or similar equipment in operation, a tremendous amount of capital must be invested in fermenters and related equipment. In addition to higher investment costs, batch processes require more labor for operation and maintenance. These factors, in addition to higher costs of raw materials, are responsible for the increasing use of synthetic ethanol, acetic acid, lactic acid, butanol, and acetone for industrial purposes.

Changes in the cost or volume of raw materials could alter this trend to synthetic products but such a reversal does not seem imminent. Development of processes for the release of fermentable sugars from cellulose or of efficient continuous fermentation apparatus, however, offer opportunities for reducing the cost of fermented products. Continued exploration of these and similar possibilities could result in increased activity in the fermentation industries.

ADVANTAGES OF BIOLOGICAL SYNTHESIS

Despite generally higher costs, biological processes are sometimes used in the production of industrial chemicals. The chief advantage of biological processes lies in the specificity of enzyme reactions. A number of organic compounds, and especially naturally occurring ones, can exist in either of two molecular forms which are mirror images of each other. These are called isomers. The separation of these forms is difficult because they react chemically and physically in an identical manner. The chief distinction between these isomers lies in their varying biological activity and in their ability to rotate a beam of polarized light which is passed through solutions containing them. The isomer which rotates the light to the left is called the *l*-form, to the right of the *d*-form. A racemic mixture of these forms consists of equal parts of the two forms and has no measurable polarizing effect on the light beam. Chemical synthesis of optically active compounds results in a racemic mixture, while biological synthesis often results in the production of one form

only. This is but a special case of the general principle that chemical reactions take place in a random fashion on equivalent atoms within a molecule, while biological action is often limited to one specific atom.

While biological methods cannot replace chemical synthesis in most cases, fermentation processes do have a definite position in synthetic chemistry. Biological processes have not yet been exploited to their fullest extent, and additional economically important processes are to be expected in the future.

Commercial Fermentations

Fermentations may be divided into four general groups:

(1) The simplest group is composed of those processses by which a substrate is converted directly to some useful product. The organism to be used is selected for its ability to produce a given compound and is cultivated in an environment conducive to maximum yields. The best known of this group of fermentations is the alcoholic fermentation. Other materials such as gluconic, acetic, lactic, and oxalic acids; acetone, butanol, 2,3-butanediol; and streptomycin, terrmycin, and penicillin may also also be produced by direct fermentation. Direct fermentations of even the above products may have a limited future because increasing pressure from synthetic products may all but eliminate many of them from the industrial market.

This trend is illustrated by the production data for ethanol. Although total alcohol production has increased, the data seem to indicate that fermentation is barely holding its own, but does not yet show a firm trend downward.

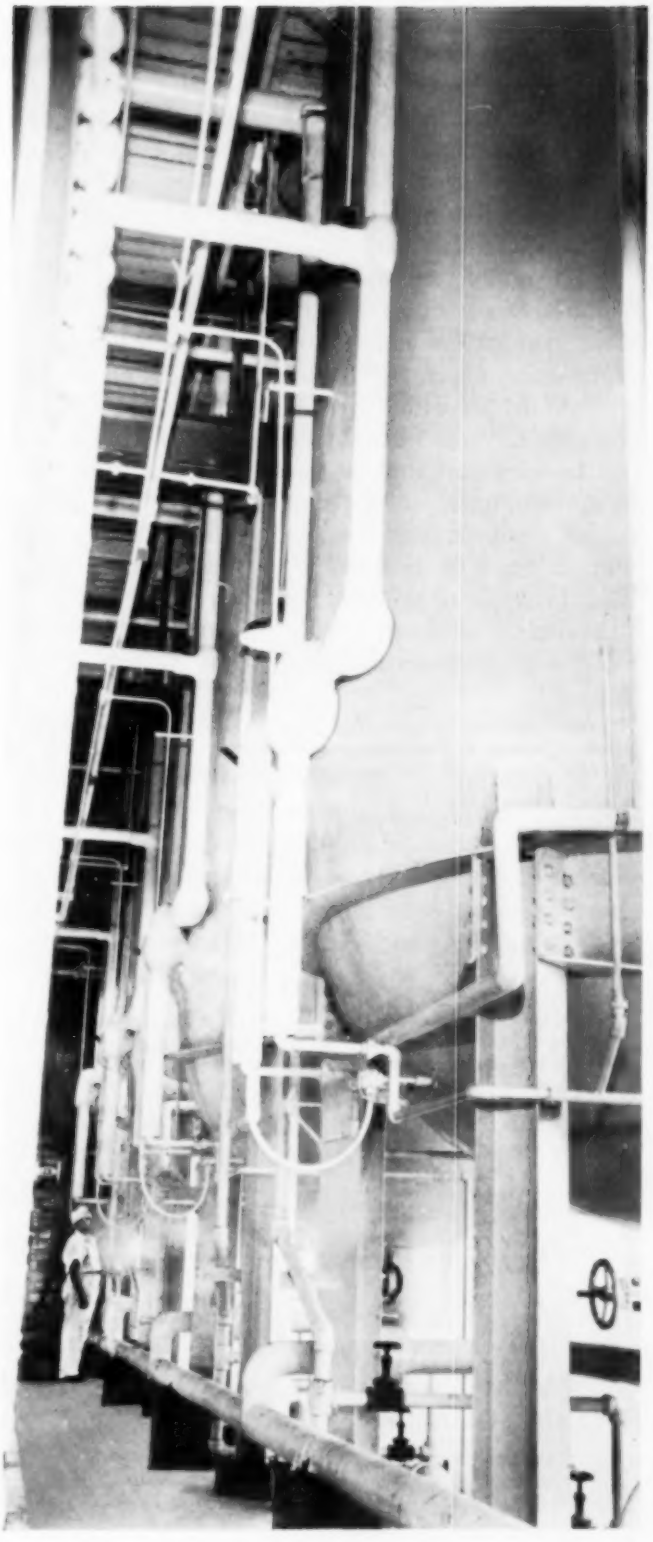
RECENT ETHYL ALCOHOL PRODUCTION

	1947	1948	1949	1950
Total Production*	149.4	171.8	187.5	203.0
Per cent by Fermentation	55	64	52	47

*millions of gallons of 95 per cent ethanol to nearest 100,000 gallons

Advances in fermentation technology will probably increase the use of biosynthesis for certain steps in the production of materials, but the decline of production by direct or complete fermentations can be expected to continue.

(2) A second group of fermentations depends upon altering the biosynthetic process normally carried on by the microorganisms. During the course of growth and multiplication, organisms require sources of energy and of raw materials which they convert to protoplasm. For example, certain yeasts are capable of converting simple nitrogen and carbon compounds



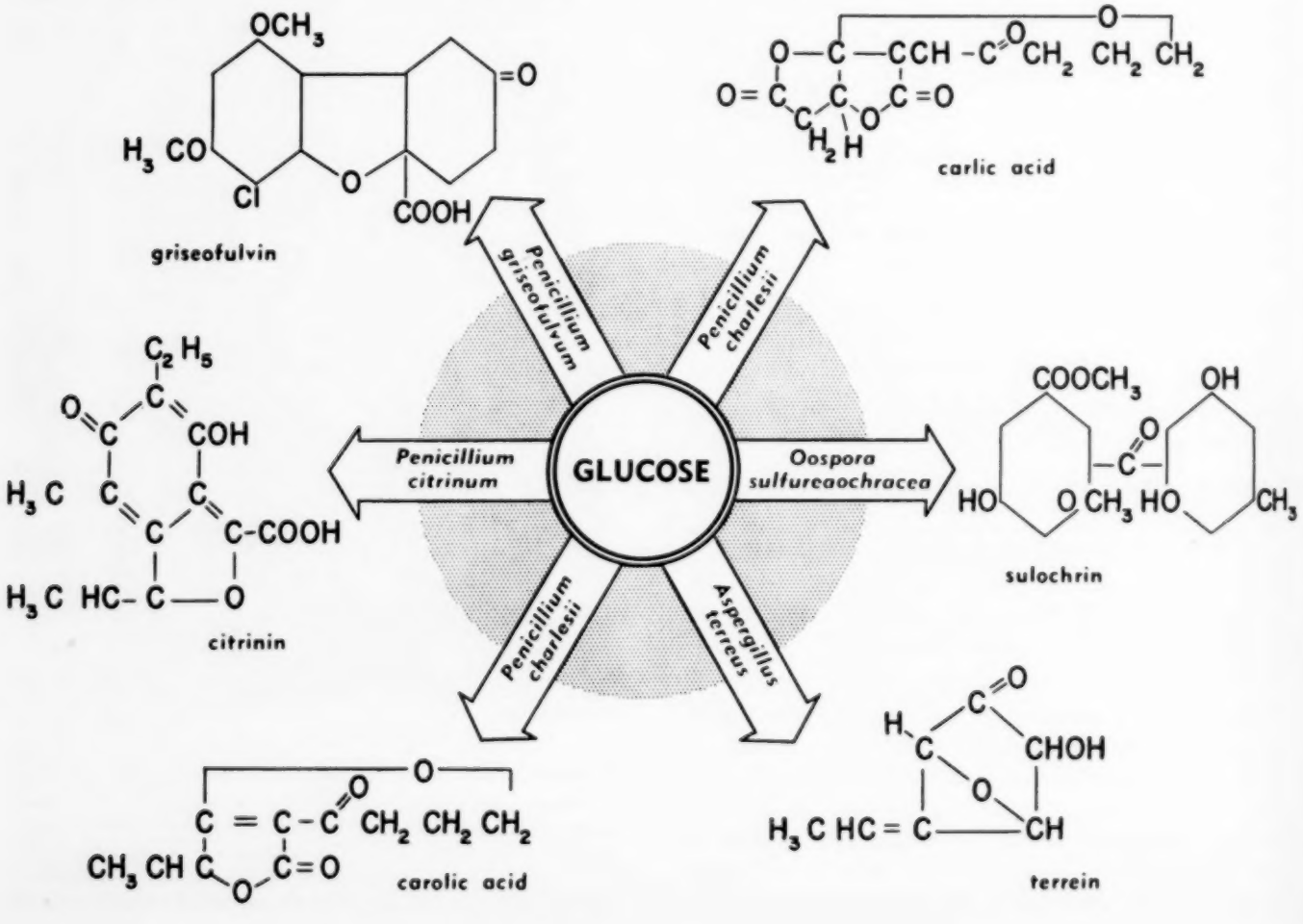
Fermentations may be carried out on a large scale as shown by these fermenters. The use of large capacity fermenters represents a practical way of simulating continuous processing since the bulk of fermented liquor is sufficiently great to permit continuous operation of separation and purification equipment. (Courtesy of Commercial Solvents Corp.)

to meet all their requirements for energy and growth. In the course of their metabolism, ethanol, glycerol, and a number of other compounds are incidentally formed. Ordinarily, alcohol is the chief product. Alcohol is not produced in one simple step, however, and in the course of the conversion, a large number of enzymes act to form a relatively large number of intermediates such as various aldehydes and acids. By using a suitable enzyme inhibitor, the process can be detoured at any of a number of stages without killing the organism. The addition of bisulfite or a number of other compounds, for example, brings about this enzyme detour with the result that alternative pathways are favored. In this manner, the yield of glycerol can be increased from a normal value of 3 per cent to approximately 40 per cent. Although this process cannot compete with chemical synthesis, it has been used in times of emergency and does demonstrate a basic principle of fermentation control.

A slightly different problem is presented by the citric acid fermentation. *Aspergillus niger* produces citric acid from sucrose and a variety of other carbohydrates. The highest yields are obtained when purified cane sugar is fermented. If molasses or other crude carbohydrate is used, gluconic and oxalic acids are produced at the expense of citric acid. Investigation has shown that the alteration in end-product balance results from the increased iron, copper, and zinc that are present in molasses and that the alteration can be avoided by suitable treatment of the substrate. Molasses may be treated with potassium ferrocyanide or may be passed through suitable ion-exchange resins to eliminate the interference of the above metals. The inclusion of ethanol, methanol, morpholine, or other materials in the fermentation medium may produce the same effect. This type of fermentation control is being used now in the production of citric acid.

The potentialities of altered metabolism are almost limitless. Interference with normal metabolism can result in the production of new products or can result in an alteration of the normal balance of end products.

A great number of complex compounds can be produced from simple materials such as glucose through the action of microorganisms. The compounds shown here are but a few of the types that may be isolated from microbial cultures and illustrate some of the reactions that may be accomplished under normal atmospheres at room temperatures.



It is also possible, by cultivation under abnormal conditions, to produce organisms with characteristics differing markedly from the parent cultures. The latter technique has been used to obtain alcohol-resistant yeasts, heat-resistant bacteria, sulfite-tolerant yeasts and organisms with other special characteristics. Some of these organisms are of economic importance.

(3) The third group of fermentations comprise those in which biological and chemical synthesis are combined. These may well be of very great importance in the future. Ephedrine, an alkaloid causing shrinkage of mucous membranes, is produced in this fashion. Although total synthesis has been successful, a racemic mixture is formed. Only the *l*-form has biological activity.

Ephedrine is now produced by utilizing yeast cells to fix the optical activity of the compound. Benzaldehyde is added to an alcoholic fermentation and, if the proper enzyme is present, it is linked to the acetaldehyde produced in the fermentation. The complex is treated with methylamine and hydrogenated to give *l*-ephedrine. The product of this synthesis is relatively pure and of high potency.

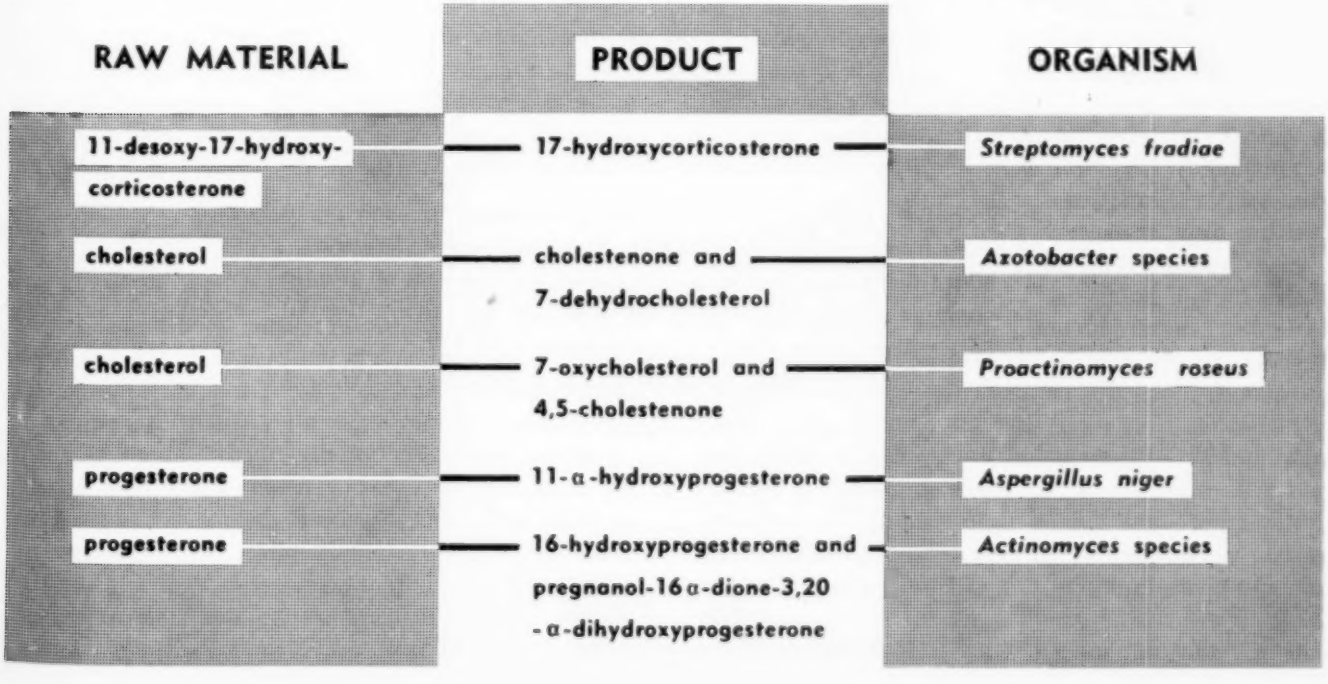
A similar process is used in the preparation of ascorbic acid (vitamin C). Sorbitol is produced by catalytic hydrogenation of *d*-glucose after which it is converted to *l*-sorbose by biological means. Further chemical treatment results in the formation of ascorbic acid. This product is used in vitamin therapy and is finding increasing use as an antioxidant, especially in the food industry.

(4) The fourth group of fermentations is composed of those in which biological methods are used to convert a material to some more valuable compound. At the present time, for instance, phenyl acetic acid, or its derivatives, is being used to increase the yield of penicillin. It is probable that a portion of this compound is incorporated into the molecule of the antibiotic with little change. Attempts are being made to find precursors for the other important antibiotics and, if they can be produced economically, the entire process of antibiotic manufacture may be radically changed.

Changes of this nature are now being made in the production of mammalian hormones. Most of the animal hormones are produced by extraction from animal tissues. Increased knowledge of their effects has resulted in an expanded demand, but there is little chance of increasing the supply of natural hormones. Microbiological transformation of steroids has been reported, and this type of reaction is now being used to increase the supply of certain hormones. Total synthesis has yet to be achieved, but further exploitation of microbiological processes may bring about this objective in the foreseeable future.

The preceding discussion has dealt with some of the important processes now being used for the preparation of commercial chemicals. Although these processes

Microbial processing is now being used in the preparation of hormones from steroids having little or no hormone activity. The transformations shown here result, in some cases, in the preparation of precursors for chemical preparation of these materials. Such processes have permitted reductions in some prices and offer hope for further production efficiencies.



are not used in the heavy chemical industry, they are practical examples of the application of fermentation techniques to problems of synthetic chemistry. While there is considerable room for improvement in the existing fermentations, it would appear that the real opportunities lie in the development of new processes.

Microorganisms can produce very complex structures from very simple starting materials. For example, sodium acetate will provide the carbon and energy required for the synthesis of microbial protoplasm. Once fermentation has taken place, a formerly simple medium may contain a great variety of closely related compounds. It may be possible to utilize these to "tailor" entirely new compounds by using microorganisms under controlled environments.

Some measure of the synthetic powers of microorganisms is shown in the charts on the previous pages. Most of the organisms listed are fungi. As yet, most of the compounds shown in the first figure have no commercial use. It has been suggested, however, that some might be used as intermediates in the production of dyes, plastics, or special lubricants, but such applications have not been explored. A recent report from the Naval Research Laboratory states that copper phthalocyanine appears to be of value in the formation of greases with high-temperature stability. Some of the anthracene derivatives produced by fungi have a similar ability to precipitate copper by forming complexes. A number of materials produced by microorganisms have the ability to form polymers, but because of cost or lack of assurance that the polymer would have unique properties, little has been done with them.

Perhaps the best application of the chemical abilities of microorganisms will involve a relatively simple transformation rather than a complete synthesis. One such transformation would be the oxidation of α-pinene to pinic acid. Present techniques of preparing pinic acid are expensive. Microbial oxidation might reduce the price by restricting side reactions. Microbial processes might also be of value in the preparation of materials used in the perfume trade.

At the present time, as a result of only limited research, microbial synthesis has found an important place in the production line of many industries. As microoganisms can perform a myriad of reactions such as oxidation, reduction, deamination, decarboxylation, dehydrogenation, etc., it appears certain that the efficient use of bacterial labor is still to be realized. Only concentrated research on applying microbial synthesis under controlled conditions to the production problems of many industries will result in the full utilization of these willing workers for the economic production of new and known materials.

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"To build a modern jet plane, over one hundred times as many engineer hours are required as were necessary twelve years ago. An hour's flight by a jet airplane demands forty hours of ground maintenance. The more complex the machine the greater the tail of skills which, like a comet, it must bear behind it."

Cornelis W. de Kiewiet in *The Scientific Monthly*

Twins in the "Wonder-Metal" Family

by JOHN M. BLOCHER

The author has been engaged in the development of extractive processes for titanium and zirconium and is author of several publications on titanium and its compounds. Dr. Blocher has also participated in research leading to the preparation of high-purity metals, among them chromium, with ductility at room temperature. He joined Battelle in 1946 after receiving his Ph.D. degree in physical chemistry from The Ohio State University.

THE ADVANCING frontiers of science and industry have created demands for new and better construction materials. Some of the applications for which the materials are needed were undreamed of before World War II. In meeting the challenge, chemists and metallurgists are making increasing use of the uncommon metals for solving difficult materials problems.

The story of how titanium metal is meeting the needs of the aircraft industry has unfolded in recent years. More will be heard of its application in places where high strength, light weight, and outstanding corrosion resistance, particularly to sea water, are required.

Zirconium is a member of the same family, having many similar characteristics, but lacking the advantage of light weight. While titanium is less than two-thirds as dense as steel, zirconium has seven-eighths the density of steel. However, this is offset by a unique combination of other properties, the discovery of which has opened up a promising future for at least small tonnages of the metal. As the cost of producing zirconium from the ore is decreased by advances in technology, more widespread use will surely follow.

PROPERTIES OF THE TWIN METALS

Zirconium has a twin brother, hafnium, so similar as to have gone along unrecognized for 134 years after the discovery of zirconium. Zircon ore, from which zirconium metal is extracted, contains about two parts of hafnium to ninety-eight parts of zirconium. Being alike in chemical nature, these "twins" are not separated in the ordinary chemical processes leading to the production of the metal. However, it was their successful separation that finally opened the future for both.

In the course of developmental work for the Atomic Energy Commission, it was recognized that, for all their chemical similarity, the two "brothers" differ widely in their tendency to absorb slow neutrons, the life blood of an atomic pile. With its superior corrosion resistance, reasonably high strength, and distaste for neutrons, hafnium-free zirconium is "practically the perfect material of construction for nuclear reactors."

This factor has been a potent stimulant to the growth of the zirconium industry. At the same time, appreciable quantities of hafnium have been made available, so that the properties and potential uses of this metal and its compounds can be studied.

The Atomic Energy Commission, after having provided an initial subsidy, is anxious to have the zirconium industry stand on its own feet. This will require the development of commercial applications divorced from the field of nuclear energy. Outstanding among these potential commercial applications is the use of zirconium for corrosion-resistant equipment in the chemical industry. For example, zirconium is the only metal, other than the precious metals, which has a resistance to hydrochloric acid comparable to that of tantalum. With a two-to-five disadvantage in density, tantalum may be economically replaced by zirconium in many instances. Unfortunately, the fabrication of zirconium into equipment, such as heat exchangers, is more difficult than in the case of tantalum. This may not always be the case, however, since rapid progress is being made in developing fabrication procedures.

Zirconium has for many years found limited use in the electron-tube industry, notably as a "getter" to remove residual gases from the tubes, thus increasing their efficiency and life span. In this application, as in its use in flash bulbs, the zirconium need not have the high purity required to give it ductility. Although zirconium will continue to be used in this manner, it is in the form of ductile alloys having high temperature strength that zirconium will find an expanding market as a material of construction in the electron-tube industry.

The tolerance of living tissue for zirconium is such

as to make it interesting for use in bone surgery. Its use in surgical tools should also increase the market.

In the nonnuclear applications mentioned above, it is not necessary to separate hafnium from zirconium. However, with the advent of widespread use of atomic power (certain to be accelerated by the recently announced successful "breeding" of atomic fuel), a large market for hafnium-free zirconium is in prospect.

Little can be said of the future for the infant, hafnium, until a more thorough knowledge of its properties is obtained. It is interesting to note, however, that the carbide of hafnium is very hard, and depending upon its resistance to oxidation, may find potential use in rocket and jet parts where high-temperature abrasion resistance is required.

Preparation of the Metals

Zirconium and hafnium, as well as titanium, have in common a high affinity for oxygen and nitrogen. The metals are embrittled by even fractional percentages of these elements, which once having been absorbed, cannot be removed. Thus, it is necessary in the preparation of the metals from their ores, to exclude air and other oxygen- or nitrogen-bearing impurities. This leads to complicated and costly procedures. Consequently, a great challenge and opportunity for the chemist and metallurgist lies in the extractive metallurgy of this family of elements.

Through the use of the "Kroll process" as developed principally at the Bureau of Mines, the price of ductile zirconium has been reduced from hundreds of dollars per pound to around ten dollars per pound. Further economies can be expected when the Kroll process, involving the batchwise reaction of zirconium chloride with magnesium, can be made continuous.

Sizeable quantities of zirconium are also being made by the thermal decomposition of zirconium iodide which yields a product of extreme purity and ductility suitable for specialized applications. Although improvements may be made in these two processes, the future of low-cost zirconium may well depend on extractive processes still in the laboratory or as yet unconceived.

Fortunately, the domestic supply of zirconium ores is adequate to meet anticipated needs. However, foreign ores have been imported because of somewhat superior quality. It is comforting to note that the foreign sources are such countries as India, Australia, and Brazil which are located in the free world.

With a partial demand already established, and a growing interest in the properties and applications of the family of "wonder metals", their significant place in the future materials economy is assured.

"A good mathematician may know the truth about numbers and a good engineer may know how to make physical forces serve his purposes. But the engineer and the mathematician are human beings first—so for them, as well as for me, what matters is not one's knowledge and skill, but one's relations with other people."

Arnold Toynbee

Notes From Battelle

HOW NATURE CONCENTRATES MINERALS

Metal technologists are greatly concerned these days with the problem of obtaining usable concentrations of metals from highly diffuse sources. It is a problem that nature has solved in a variety of interesting ways through the needs of both animals and plants.

The ocean is a rich, though dilute, source of many minerals. It is not surprising, therefore, to find forms of animal and vegetable life that gather these minerals for their own use. Oysters, for example, are good extractors and concentrators of copper and zinc from the sea. Another shell-fish uses strontium carbonate for the building of his house. Diatoms use silica for their skeletons, while lobsters and mussels remove cobalt from sea water. Seaweed, on the other hand, is so efficient in collecting and concentrating potassium and iodine that the minerals have been recovered commercially from that source.

On land, various types of plant life are also fairly efficient mineral concentrators. Hickory ash, to take one outstanding example, may run up to 37 per cent alumina, and in Maryland, the rare earth content of the ash has run to 0.2 per cent. The leaves of the hickory tree may give an ash containing over 4 per cent manganese. Brazil nuts may contain up to 0.4 per cent barium, while muskmelon leaves often contain the same amount of boron. Horsetail has been found to contain up to 4½ ounces of gold per ton, an enrichment factor of 600 over the gold in the soil.

A recent survey of various coal deposits has shown that some ancient plants were excellent concentrators of germanium. As much as 7 per cent germanium was found in some logs of the carbonaceous age. This has stimulated the search for modern plants that do likewise. The ash of the leaves and bark of some plants growing in areas where a trace of germanium can be detected in the soil water actually has shown up to about 5 per cent germanium.

Astralagus, a species of vetch, grows well only in soil containing selenium and has been known to build up concentrations of 1.5 per cent of the metal. Because of present demands for selenium, and the difficulty of concentrating the metal, serious thought has been given to the possibility of growing such plants commercially and extracting selenium from their ash. The extraction part has been worked out. The feasibility of large-scale plant farming must be proved.

Bruce Gonser, technical director at Battelle, has made some study of the natural concentration of minerals. He believes that in some cases it may be feasible to make direct use of the natural mineral-concentrating abilities of animals and plants. He is of the opinion, however, that a study of the mechanisms by which they are able to gather minerals would be more valuable. Such an investigation could well contribute to the development of more workable and efficient methods for extracting useful amounts of needed minerals from soil or water.

PROTECTING OFFSHORE EQUIPMENT

Oil-well drilling in offshore and tidewater locations brings serious corrosion problems. Equipment subjected to such use undergoes corrosive attack by salt water, marine atmosphere, and a deadly combination of both. The portion of the equipment covered by the tide or exposed to splashing water is most vulnerable to corrosive attack.

Corrosion technologists have found that equipment requires a different type of protection for each kind of attack. Strangely enough, the problem of protecting underwater structures was the first to be solved quite satisfactorily. Cathodic protection, a method that employs an electric current to ward off corrosive attack, can prevent the corrosion of steel under water almost completely. Through the use of sacrificial magnesium anodes, the cost of protection may be as low as 4 cents per square foot.

G. A. Hudson and B. G. Brand of Battelle's organic coatings division point out, however, that the protection of exposed and periodically submerged equipment is a more difficult and costly matter. Partially submerged equipment is exposed not only to water and the atmosphere but also to attack by highly alkaline mud and well fluids. In addition, some of the surfaces are periodically subject to cathodic protection and must be resistant to cathodic reduction products.

The selection of vehicles, pigments, and solvents that will combine for effective protection requires the most careful study. Research has led coatings technologists to regard a three-coating system as supplying the best protection for offshore equipment. A primer coat is needed to passivate the metal and cling to its surface. A second coat, containing large amounts of corrosion-inhibiting pigments, will provide protection

against corrosive action. Finally, a tough corrosion-resistant finish coat is needed to resist mechanical abuse and to effectively seal off the entire coating system.

RESEARCH TEAM

Intensified research in information processing has resulted in three additions to the Battelle staff. James W. Perry, Madeline Berry, and Allen Kent previously worked as a team at the Massacusetts Institute of Technology, where they pioneered in the development of more efficient methods for storing and sorting technical information. Under the direction of Perry, the team has made contributions in coordinate indexing, semantic factoring of terminology, and other specialized techniques for the use of manual devices and automatic machines in information processing.

Before joining Battelle, Perry was engaged in research on detergents and explosives and later served as associate professor in the modern language department at MIT. While there, he investigated the application of high-speed selecting devices to search for and to correlate scientific information. He is author or co-author of books on surface-active agents, the application of punched cards to science and industry, and technical Russian. Along with other professional society activities, Perry has served as chairman of the American Chemical Society's Committee on Scientific Aids to Literature Searching since 1947.

Miss Berry began her career as an analytical chemist and has become the team's expert in chemical nomenclature. She is co-author with Perry of the revised edition of *Punched Cards, Their Application to Science and Industry.* She is an active member of the American Chemical Society and the American Documentation Institute, among others.

Before joining Perry at MIT, Kent was associate editor of Interscience Publications. Trained in chemistry, he is a member of the Committee on Special Classifications of the Special Libraries Association.

BUILDING NUMBER SEVEN

The continuing expansion of Battelle's research activities has made the construction of a new laboratory building necessary. The new structure—Battelle's seventh—will go up beside the "special purpose" laboratory building that is now being rushed to completion.

Ground has already been broken for the new building, which will cost about $1,400,000. When completed, it will add 100,000 square feet to the floor area of the Institute's Columbus research center. This will increase the total floor space to over 17 acres. The plans for the four-story brick and concrete structure call for space for pilot plants for chemical engineering studies as well as for laboratory facilities. The new building will help meet the space requirements for additional research for industry and government.

ALUMINUM IN IRON AND STEEL

Uses as an alloy element and as a coating for other metals have played a significant part in the growing importance of aluminum. Now, for the first time, a major work has been published on the utilization of aluminum in ferrous metallurgy. The monograph, *Aluminum in Iron and Steel,* was written by Samuel L. Case, technical consultant at Battelle, and Kent R. Van Horn, director of research at the Aluminum Company of America. It is a work in the "Alloys of Iron Research Monographs" series which is under the editorship of Frank T. Sisco and published by John Wiley & Sons.

The following listing of the chapters of the book provides some idea of the breadth of its coverage. Chapter subjects include deoxidation of steel, oxide inclusions, other inclusions, aluminum and grain-size control, aluminum properties in steel, aging of steel, constitution diagrams, manufacture of iron-permanent alloys, aluminum in nitriding steels, aluminum coatings and miscellaneous uses of aluminum.

According to *The American Metal Market,* the work of Case and Van Horn "is likely to point to further outstanding developments in the many uses of aluminum and progress in the discovery of new special alloys".

SECOND GILLETT LECTURE

The Gillett Memorial Lecture, a regular feature of the annual meetings of the American Society for Testing Materials, presents leaders in the metals field. It is jointly sponsored by the ASTM and Battelle as a memorial to Horace W. Gillett, a great metallurgist and Battelle's first director. The 1953 lecture, on "Micro-Metallurgy", was presented by Jerome Strauss, Vice President of the Vanadium Corporation of America.

In his introductory remarks, Mr. Strauss related some of his memories of Gillett. The main body of the lecture, however, was concerned with a review of the increasing body of knowledge pertaining to the effects of minute changes in composition upon metals and alloys. It was an unique presentation, because it covered a very wide range of metallurgical experimentation and practice. The lecturer limited himself to "beneficial" changes in composition but traversed the field from semiconductors to carbon steels.

RECENT PAPERS AND ARTICLES BY THE RESEARCH STAFF*

Aluminum in Iron and Steel. S. L. Case and K. R. Van Horn. John Wiley & Sons, New York, 1953.

Low-Frequency Self-Generated Oscillations in the D-C Carbon Arc. B. H. List and T. B. Jones. *Electrical Engineering*, July, 1953.

Comparison of Tests for Hardenability of Shallow-Hardening Steels. G. K. Manning. *Society of Automotive Engineers, Journal*, July, 1953.

A General Comparison of the Metallurgy of Zirconium with That of Better-Known Commercial Metals. A. D. Schwope. A paper in the book, *Zirconium and Zirconium Alloys*, American Society for Metals, 1953.

New Ore Treatment Permits Wide Use of Nonmagnetic Taconites. F. M. Stephens, Jr., Benny Langston, and A. C. Richardson. *Iron Age*, July 2, 1953.

Engineering Economics. The Science of Being Practical About Marketing New Ideas and New Products. W. L. Swager. *Stove Builder*, July, 1953.

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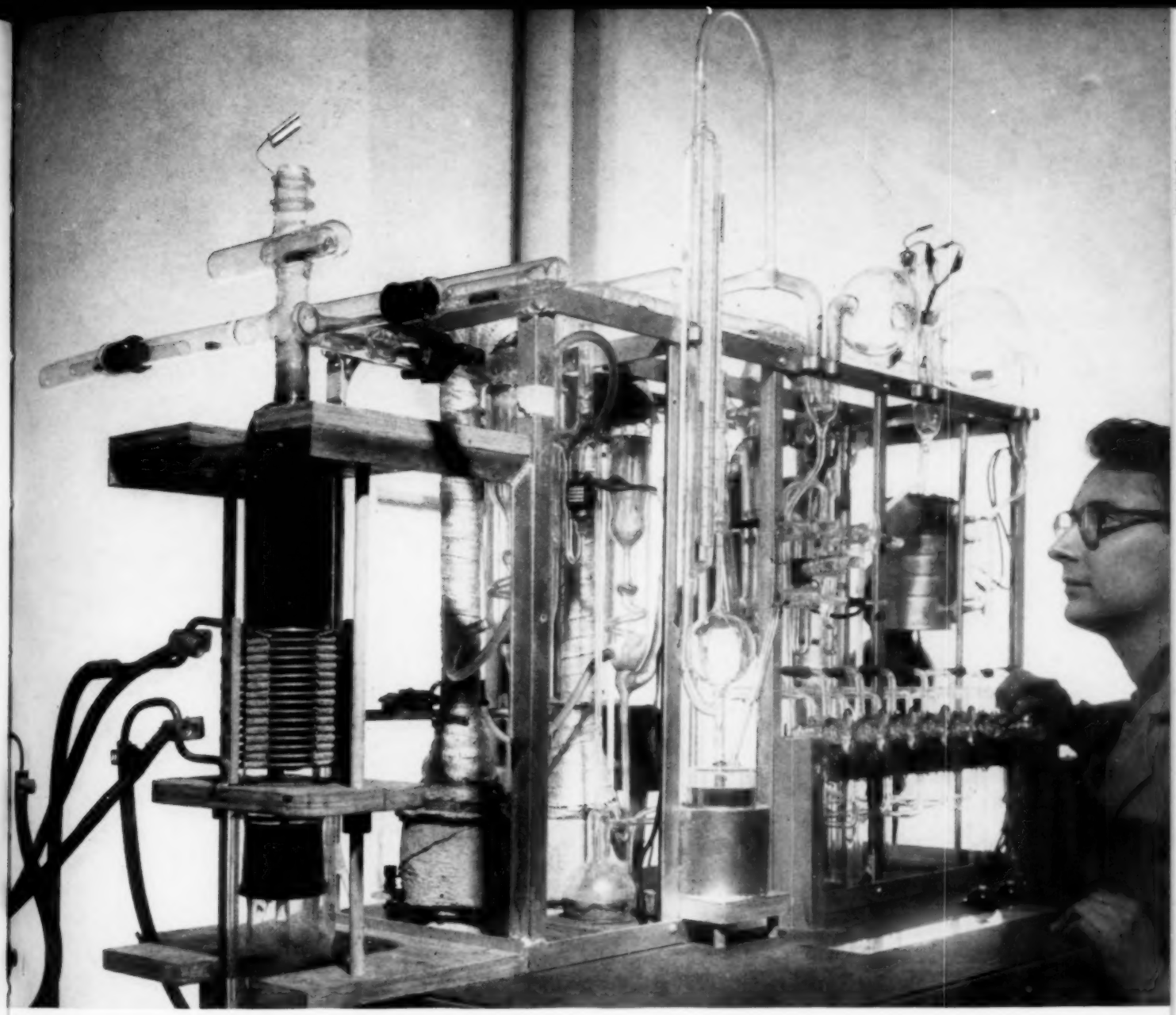
*In most cases, reprints will be available from the Battelle Publications Office on request.

A Word About Battelle Technical Review Abstracts

The abstracts that appear in the following pages are prepared from approximately 1000 American and foreign technical journals, as well as from books and other literature received in the Battelle Library. Prepared by a professional staff trained in various technological fields, the abstracts are selected for their usefulness to the Battelle research staff. They are now being made available to technologists and scientists in industry and research in all parts of the world, through the pages of the *Battelle Technical Review*.



MEASURING TO MILLIONTHS

The vacuum-fusion apparatus above was built at Battelle, and it is used for determining the precise amounts of oxygen, nitrogen, and hydrogen in metals. It is valuable in investigations of the effects of the presence of small amounts of gases in metals. Used especially in studies of such metals as uranium, thorium, zirconium, titanium, and molybdenum, the apparatus can measure hydrogen with a precision of one part in ten million by weight and oxygen and nitrogen to one part in a million.

BATTELLE INSTITUTE was founded by the will of Gordon Battelle as a memorial to the Battelle family. The Battelles were among the first settlers of Ohio and were prominent in the development of the state's iron and steel industry.

Gordon Battelle, last of the family line, was impressed with the benefits to be derived from industrial research and left his estate for the building and endowment of an Institute "for the purpose of education . . . the encouragement of research . . . and the making of discoveries and inventions for industry." The Institute began operations in 1929.

As established, Battelle provides, on a not-for-profit basis, the physical plant, equipment, and personnel for conducting research. The great bulk of it is applied research conducted for industry and government.

In keeping with its educational function, the Institute also conducts fundamental or basic research. The results of much of this research are published for the general encouragement of science and industry, and to benefit the public welfare.

Fields of research at Battelle include agriculture and practically all the industrial and engineering sciences.

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